Bellcomm

955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

date: June 1, 1971

to: Distribution

from: W. Levidow

B71 06001

subject: Skylab Typical Momentum Desaturation Maneuvers - Case 620

ABSTRACT

The Skylab Orbital Assembly will execute momentum desaturation maneuvers on the dark side of the orbit in order to remove CMG bias momentum.

This memorandum describes typical maneuvers based on current desaturation procedures and current estimates of vehicle inertia properties and disturbance torques. They yield a maximum maneuver angular velocity of .028 degrees/sec and a maximum rotation from solar inertial attitude of 11.7 degrees.

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MEMORANDUM FOR FILE

INTRODUCTION

The Skylab Orbital Assembly (OA) will execute momentum desaturation (dump) maneuvers on the dark side of the orbit in order to remove CMG bias momentum. The bias momentum results from bias components of disturbance torques acting on the vehicle.

This memorandum describes typical dump maneuvers which the OA will execute in accordance with the dump procedures defined in the Program Definition Document, Chapter 10, November 4, 1970 and modified by working notes from H. Kennel of MSFC. The maneuvers were obtained by a simulation of the vehicle dynamics, the disturbance torques, and the dump procedures. The results yield a maximum maneuver angular velocity of .028 degrees/sec and a maximum rotation from solar inertial of 11.7 degrees.

DISTURBANCE TORQUES

The significant disturbance torques are those due to gravity gradient, aerodynamic drag, venting, and leakage.

The bias momentum resulting from gravity gradient torque depends upon the vehicle inertia properties and Beta (β).* With the X principal axis in the orbital plane, bias momentum accumulates only along the X principal axis and is proportional to the difference between the intermediate and maximum principal moments of inertia. The OA considered here[1] has the following inertia properties (slug-ft^2).

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*β = angle from orbital plane to earth-sun line, positive when sun is northerly.

$$I^{body} = \begin{bmatrix} 725689 & -10290 & -288117 \\ -10290 & 4493597 & -23589 \\ -288117 & -23589 & 4440925 \end{bmatrix} \quad \text{slug-ft}^2$$

$$I^{principal} = \begin{bmatrix} 703439 & 0 & 0 \\ 0 & 4505749 & 0 \\ 0 & 0 & 4451008 \end{bmatrix} \quad \text{slug-ft}^2$$

The bias momentum vector due to aerodynamic drag is directed almost perpendicular to the orbital plane. It is maximum at $\beta=0$. For the air density model considered here[2], aerodynamic drag results in a maximum bias momentum of 150 ft-lb-sec per orbit directed northerly.

Venting torque results from the propulsive effect of gases deliberately released from the vehicle. The venting model considered here[3] assumes a constant venting torque resulting in per orbit bias momentum along the X, Y, Z body axes of -275, 730, -640 ft-lb-sec.

Leakage torque results from cabin atmosphere leaking out of the pressurized modules of the OA. The leakage model considered here[4] results in a per orbit bias momentum magnitude of 725 ft-lb-sec. The direction of the bias momentum vector is unknown but it is assumed, for each orbit, to be fixed in the OA and normal to the orbital plane during solar pointing. Its assumed direction is such that it makes an angle equal to or less than 90° with the venting bias momentum vector; thus the two bias momentum vectors do not tend to cancel.

$\underline{\nu_Z}$

During solar pointing the Z body axis will point to the sun. However, the X body axis will be displaced from the orbital plane by a small roll angle, ν_Z, about the Z body axis. In the absence of all disturbance torques but gravity gradient, ν_Z should be such that the X principal axis, not the body axis, lies in the orbital plane. In this attitude, gravity gradient bias momentum accumulates only along the X principal axis and its magnitude is minimized. The particular value of ν_Z, $\nu_{Z,gg}$, which accomplishes this is given by

$$\nu_{Z,gg} = \sin^{-1}\left\{\frac{-K_{13}\tan\beta}{(K_{11}^2+K_{12}^2)^{1/2}}\right\} - \tan^{-1}\left\{\frac{K_{12}}{K_{11}}\right\} \qquad (1)$$

where K_{ij} are the elements of the direction cosine matrix which transforms a vector from the body to the principal axes coordinate system.

Any change in ν_Z from the attitude defined by Equation (1) results in additional gravity gradient bias momentum whose direction (called orbital Z) is essentially along the line from earth center to orbit noon. Hence, any bias momentum along orbital Z resulting from disturbance torques other than gravity gradient can be cancelled by a slight displacement, in the proper direction, of the X principal axis from the orbital plane.

For this reason, ν_Z during the Skylab mission will not be set as defined by Equation (1) but will differ from it by an amount sufficient to null the total orbital Z bias momentum. This will leave only the orbital Y (perpendicular to the orbital plane) and the X axis bias momentum to be dumped by the night-time dump maneuvers. However, Equation (1) (or equivalent) will be used to initialize the vehicle attitude for the first orbit.

The proper value of ν_Z will be attained during the mission by a momentum sampling method which determines the bias momentum and calculates orbit by orbit changes ($\Delta\nu_Z$) in ν_Z in order to continually cancel the orbital Z component. Some change in the orbital Z component may be due to vehicle attitude drift resulting from Z axis rate gyro drift. In nulling this bias change, $\Delta\nu_Z$ also automatically corrects this attitude drift.

Figure 1 shows the proper ν_Z as a function of β for the OA and disturbance torques considered here. It ranges from +17° to -19°.

$\underline{\eta_{TM}}$

Momentum dump maneuvers are calculated on the basis of a dump interval symmetrical about the point (dump midnight) in orbit during orbital night at which the X principal axis is tangent to the orbit. The angular displacement of dump midnight from orbital midnight is called η_{TM} and is positive about the orbital north direction. It will be calculated each orbit just prior to the dump maneuvers by

$$\eta_{TM} = \tan^{-1} \frac{[(K_{11}S\nu_Z + K_{12}C\nu_Z)S\beta - K_{13}C\beta]}{[K_{11}C\nu_Z - K_{12}S\nu_Z]} \qquad (2)$$

ν_Z, as required in Equation (2), will be obtained from star tracker measurements. If star tracker output is not available, then ν_Z will be approximated by $\nu_{Z,gg}$ as calculated by Equation (1).

Figure 1 shows η_{TM} vs. β as calculated by Equation (2). It ranges from -4.4° to -19.4°.

$\underline{\rho_D}$

The dump maneuvers will occur over an orbital angle ρ_D either side of dump midnight (DM), and normally will not extend into the sunlit sector. If ρ is the orbital angle between orbital midnight (OM) and orbital sunrise (OSR) (or orbital sunset (OSS)), then

$$\rho_D = \rho - |\eta_{TM}| \qquad (3)$$

The spatial relationship between ρ, η_{TM}, and ρ_D is shown in Figure 2 (η_{TM} is shown negative because the current OA inertia properties produce negative values. This makes Figure 2 more representative of the actual mission.).

For orbits with small or no dark sector, a minimum of 54° (30%-orbit dump interval) for ρ_D is currently planned. This will be increased to 63° (35°-orbit dump interval) during the mission if required by contingencies (2 CMG operation, excessive venting or leakage torques, etc.).

The values of ρ_D as calculated from Equation (3) (imposing the 54° lower limit) are also shown in Figure 1.

DUMP MANEUVERS

The dump maneuvers consists of three constant angular velocity rotations: $\underline{\omega}_1$, $\underline{\omega}_2$, and $\underline{\omega}_3$. The first occurs over one fourth the total dump interval, the second over the following one half interval, and the third over the remaining one fourth interval. $\Delta\nu_Z$ is incorporated into the third maneuver so that the vehicle returns to solar inertial attitude with a new value of ν_Z. The spatial relationship of the three maneuvers is shown in Figure 2.

Table 1 displays the dump maneuvers required at several values of β. Since the vehicle is in solar inertial attitude before and after the maneuvers, the first and third maneuvers indicate the rotations required from solar inertial. They are essentially about the Y and Z body axes. The maximum angular velocity is .028 degrees/sec and the maximum rotation angle is 11.7 degrees. This can be achieved by CMG control unaided by TACS.

As the model of vehicle inertia and venting and leakage torques are refined, these maneuvers will change somewhat due to changes in bias momentum to be dumped.

W. Levidow

1022-WL-jf W. Levidow

Attachments
Figures 1 - 2
Table 1
References

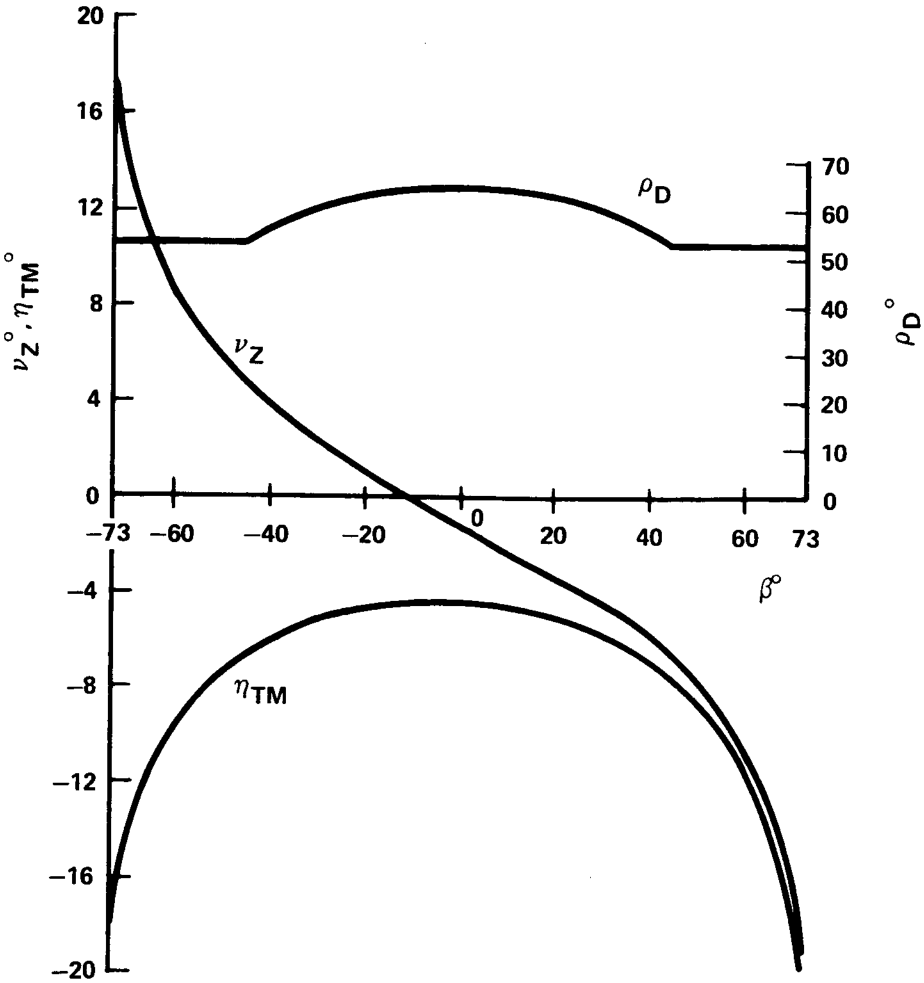

FIGURE 1 ν_z, η_{TM}, AND ρ_D VS β

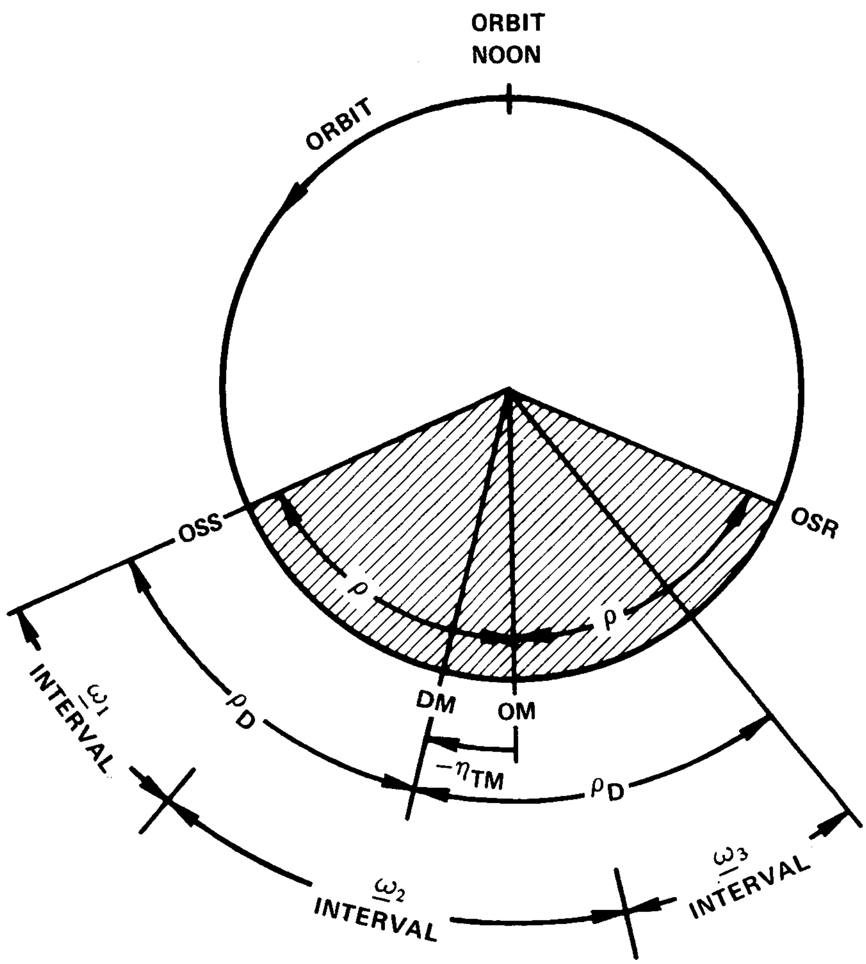

FIGURE 2 - DUMP MANEUVER ORBITAL GEOMETRY

TABLE 1

Momentum Dump Maneuvers

β°	First Maneuver			Second Maneuver			Third Maneuver		
	$\underline{e}$	$\lvert\underline{\omega}\rvert$	ϕ	$\underline{e}$	$\lvert\underline{\omega}\rvert$	ϕ	$\underline{e}$	$\lvert\underline{\omega}\rvert$	ϕ
73	.003 .932 .364	.019	7.8	-.097 -.957 .272	.015	12.2	.087 .585 -.806	.018	7.7
60	.006 .979 .205	.014	5.8	-.103 -.865 .492	.010	8.7	.097 .314 -.944	.014	5.8
30	.066 -.853 -.517	.013	6.2	.014 -.505 .862	.000	0.4	-.064 .881 .468	.013	6.2
0	.046 -.997 -.066	.019	9.6	-.040 -.005 .999	.003	1.4	-.027 .996 -.083	.019	9.6
-30	.022 -.990 .137	.022	10.5	-.068 .501 .863	.008	7.9	.093 .614 -.784	.022	10.4
-60	-.004 -.951 .310	.027	11.3	.007 .880 .474	.019	16.2	.093 -.301 -.949	.028	11.7
-73	-.028 -.898 .439	.028	11.6	.046 .960 .276	.020	17.1	.060 -.529 -.846	.027	11.5

$\underline{e}$ = Unit rotational vector in body axes coordinates about which vehicle rotates.

$\lvert\underline{\omega}\rvert$ = Magnitude of angular velocity, degrees/sec.

ϕ = Angle through which vehicle rotates, degrees.

REFERENCES

1. Skylab A Orbital Mass Properties, S&E-ASTN-SAE Program WP978, MSFC, April 26, 1971.

   Run 53, Event 15, Skylab 4 CSM docked to Port V, Three men and equipment in OWS.

2. Purkey, R. C., "A Computer Routine for the Compution of Jacchia Atmospheric Density", Bellcomm Memorandum for File, B69 03092, March 25, 1969.

3. Levidow, W., "Effect of Venting and Leakage Torques on Attitude Control of the Skylab Orbital Assembly by CMGS", Bellcomm Technical Memorandum, TM-71-1022-1, March 2, 1971.

4. Smith, P. G., "Skylab Leakage Propulsion Models", Bellcomm Memorandum for File, B71 03005, March 2, 1971.

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